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Regression analysis as a cost estimation model for unexploded ordanace cleanup at former military installations

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THESIS

REGRESSION ANALYSIS AS A COST ESTIMATION MODEL FOR UNEXPLODED ORDNANCE CLEANUP AT FORMER MILITARY INSTALLATIONS

by

Ronald B. Ross

June 2002

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Throughout the 1990s, the Department of Defense has undergone numerous changes in an effort to save money and bring the military infrastructure in line with the National Security Strategy. One of the major ways of reducing military infrastructure has been through the Base Realignment and Closure program. Before an installation can be formally turned over to the local community, the military service owning the base has to certify that the land is environmentally safe for reuse. One of the greatest problems discovered on former weapons training installations is the numerous pieces of Unexploded Ordnance that were located either on the surface or just below the surface in soil that will be reworked for land development projects by local city developers. This thesis provides a comprehensive case study of the former Fort Ord installation as the Army goes through the process of cleaning up Unexploded Ordnance so that the property can be given to the City of Seaside, CA and other civilian entities. A mathematical model is developed to better estimate cleanup costs using historical cost data that could be used by the Defense Department prior to placing installations on any future closure lists.

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REGRESSION ANALYSIS AS A COST ESTIMATION MODEL FOR UNEXPLODED ORDNANCE CLEANUP AT FORMER MILITARY INSTALLATIONS

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ABSTRACT

Throughout the 1990s, the Department of Defense has undergone numerous changes in an effort to save money and bring the military infrastructure in line with the National Security Strategy. One of the major ways of reducing military infrastructure has been through the Base Realignment and Closure program. Before an installation can be formally turned over to the local community, the military service owning the base has to certify that the land is environmentally safe for reuse. One of the greatest problems discovered on former weapons training installations is the numerous pieces of Unexploded Ordnance that were located either on the surface or just below the surface in soil that will be reworked for land development projects by local city developers. This thesis provides a comprehensive case study of the former Fort Ord installation as the Army goes through the process of cleaning up Unexploded Ordnance so that the property can be given to the City of Seaside, CA and other civilian entities. A mathematical model is developed to better estimate cleanup costs using historical cost data that could be used by the Defense Department prior to placing installations on any future closure lists.

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LIST OF SYMBOLS, ACRONYMS AND/OR ABBREVIATIONS

AM	Action Memorandum
ACV	Actual Cost Variances
ACWP	Actual Cost of Work Performed
BCWP	Budgeted Cost of Work Performed
BRAC	Base Realignment and Closure
Cal/EPA	California Environmental Protection Agency
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DBCRA	Defense Base Closure and Realignment Act
DDESB	DOD Explosives Safety Board
DERP	Defense Environmental Restoration Program
DOD	Department of Defense
DTSC	Department of Toxic Substances
EDA	Economic Development Administration
EDL	Endangered Species List
EE/CA	Engineering Evaluation/Cost Analysis
EPA	Environmental Protection Agency
ESA	Endangered Species Act
FTC	Fast Track Cleanup
GAO	General Accounting Office
HASC	House Armed Services Committee
MBCWP	Model Budgeted Cost of Work Performed
MCV	Model Cost Variance
NDAA	National Defense Authorization Act
NEPA	National Environmental Policy Act
NPL	National Priority List
NTCRA	Non-Time-Critical Removal Action
OEC	Office of Environmental Cleanup
PA	Preliminary Assessment
PM	Program Managers
Post-RA	Post-Removal Action
RA	Removal Action
RACER	Remedial Action Cost Engineering and Requirements
RD	Removal Design
RI/FS	Remedial Investigation/Feasibility Studies
RPM	Remedial Project Managers
SASC	Senate Armed Services Committee
SECDEF	Secretary of Defense
SI	Site Investigation
USACE	United States Army Corps of Engineers
UXO	Unexploded Ordnance
$TC	Total Cost

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I. INTRODUCTION

A. BACKGROUND OF BRAC

From the end of the Vietnam War until the late 1980s, congressional concern about the potential loss of jobs in local communities resulted in very few bases being studied or recommended for closure or realignment. These circumstances prevented DOD from adapting its base structure to significant changes in forces, technologies, organizational structures, and military doctrine. The end of the Cold War, and the associated reductions in the size of the military, increased the number of installations that were candidates for closure and realignment.

To address this problem, Congress created the Base Realignment and Closure (BRAC) process, which works as follows: DOD carefully evaluates and ranks each base according to a published plan for the size of future military forces using published criteria, adopted through a rule-making process prior to each round. The criteria have been the same for each of the four rounds of BRAC and have included military value, return on investment, environmental impact, and economic impact on the surrounding communities. The Secretary of Defense then recommends to an independent BRAC Commission bases for closure and realignment. The Commission, aided by the General Accounting Office (GAO), performs a parallel, public review of these recommendations to ensure that they are, indeed, consistent with the Department’s force structure plan and selection criteria. It then submits its recommendations to the President. The President and Congress must either accept these recommendations in total or reject the entire package. To date there have been four

BRAC rounds approved by Congress: BRAC 88, BRAC 91, BRAC 93, and BRAC 95.[Ref. 1]

B. BACKGROUND OF THE FORMER FORT ORD MILITARY INSTALLATION

In 1917, the U.S. Army bought the present day East garrison and nearby lands on the east side of Fort Ord to use as a maneuver and training ground for field artillery and cavalry troops stationed at the Presidio of Monterey, CA. Before the Army's use of the property, the area was agricultural, as is much of the surrounding land today. Beginning with its founding in 1917, Fort Ord served primarily as a training and staging facility for infantry troops. From 1947 to 1975, Fort Ord was a basic training center. After 1975, the 7th Infantry Division (Light) occupied Fort Ord. Light Infantry troops operated without heavy tanks, armor, or artillery. Fort Ord was selected in 1991 for Base Realignment and Closure (BRAC), but troop reassignment was not completed until 1994 when the post formally closed.[Ref. 2]

C. OBJECTIVE

The objective of this research was to provide a comprehensive case study of the former Fort Ord installation as the Army goes through the process of cleaning up Unexploded Ordnance (UXO) and turning the land over to the City of Seaside, CA and other civilian entities. This project also provides a mathematical model to better estimate the cost of UXO cleanup using historical cost data that could be used by DOD prior to placing other installations on any future BRAC lists.

D. RESEARCH QUESTIONS

The primary research question is:

What are the cost drivers associated with the cleanup of Unexploded Ordnance at BRAC sites?

The following secondary questions are developed to help clarify and supplement the primary research question:

1. What is BRAC and how do environmental laws affect the process?

2. What are some of the methods used to clean up UXO and how do they vary from one another?

3. What is the current method used to provide UXO clearance estimates and is a better mathematical model for estimation possible?

E. SCOPE & LIMITATIONS

The scope includes:

1. A case study of the process involved in UXO cleanup of former military installations.

2. A discussion of the major legislation and directives governing UXO cleanup.

3. A development of a mathematical model using historical cost data and an assessment of its use within DOD.

This case study is limited to the former Fort Ord military installation. The mathematical model utilizes cost data from 20 sites located on the former Fort Ord.

F. ORGANIZATION OF THE STUDY

Chapter II provides an overview of major legislation affecting environmental cleanup of UXO. Included in Chapter II are National and Defense related legislation. Chapter III takes a detailed look at studies required prior to environmental cleanup of UXO to include assessments, investigations, analysis, and action plans. Chapter IV provides a list of major organizations and their roles relating to UXO cleanup. Chapter V describes various methods used for vegetation clearance throughout the environmental cleanup industry. It provides both pros and cons for each alternative. Chapter VI presents a description of acquired data, an overview of regression analysis, the regression outcome, and a comparison between the former Fort Ord model and the developed mathematical model using regression analysis. Finally, Chapter VII delivers conclusions and recommendations for further study.

II. OVERVIEW OF MAJOR LEGISLATION AFFECTING ENVIRONMENTAL CLEANUP OF UXO

Preservation of the environment has become a major source of conversation these days. Society has been able to advance technologically in many areas for decades, but has failed to come up with suitable alternatives to solve the problem of environmental contamination.

Since World War II, the United States has been the leading producer of the world's consumer products. The United States, through its technological advances, has put together the most formidable military force in the world, but not without paying a heavy price.

To ensure its military is at its best at all times, the Department of Defense has invested heavily in the training of its armed forces, especially through live ammunition training. Due to downsizing of military forces and infrastructure, DOD has discovered how much contamination has been left behind from live ammunition training on former military installation. The cleanup of Unexploded Ordnance has become a high priority and DOD is taking necessary steps to eliminate the problem.

This chapter will discuss the major legislation affecting environmental cleanup of UXO at former military installations. Legislation to be discussed includes federal, local, and defense related regulations.

A. DEFENSE AUTHORIZATION AMENDMENTS AND BASE CLOSURE AND REALIGNMENT ACT OF 1988 (BCRA 88)

The Defense Authorization Amendments and Base Closure and Realignment Act of 1988 (Public Law 100-526) provided the Secretary of Defense with the authority to close all military installations that were provided to him in a written report by a 12-member committee, appointed by the Secretary and known as the Commission on Base Realignment and Closure. It also provided the Secretary with the authority to realign all military installations recommended by the Commission, and to initiate and complete closure of these facilities within a four-year period.

To ensure that there was a form of checks and balances concerning recommended closures, Congress permitted the Secretary of Defense to carry out these closures only after he had provided to both the House Armed Services Committee (HASC) and Senate Armed Services Committee (SASC) his personal approval. He was to provide to the HASC and SASC a study of military installations outside the United States detailing if any efficiencies could be achieved through closure or realignment of these facilities. He could not take any action if a joint resolution was enacted disapproving the recommendations of the Commission within 45 days beginning March 1, 1989.

The Act provided the Commission with an outline of their duties, required that no more than one-half of their professional staff consisted of DOD employees, made available to the Secretary specific guidance on the management and disposal of property, the applicability of any other laws that were to be adhered to, waiver requests, and funding administration.[Ref. 3]

B. NATIONAL DEFENSE AUTHORIZATION ACTS

1. Defense Base Closure and Realignment Act of 1990

The Defense Base Closure and Realignment Act of 1990 (DBCRA 90) provided a process designed to result in the timely closure and realignment of military installations through a detailed organizational plan. The Act required the establishment of an independent commission known as the Defense Base Closure and Realignment Commission.

The Commission was to consist of eight members appointed by the President of the United States under the advise and consent of Congress. The DBCRA 90 outlined administrative provisions relating to the membership and duties of the Commission, special conditions required by the Commission and the Secretary of Defense regarding potential closures and realignments, actual implementation of closures and realignments by the Secretary of Defense, the applicability of other laws and regulations with emphasis on the National Environmental Policy Act (NEPA), waiver considerations, the requirements of reports and studies, and finally the establishment of the Department of Defense Base Closure Account for funding purposes.[Ref. 4]

2. National Defense Authorization Acts for Fiscal Years 1992 and 1993

The National Defense Authorization Acts for FY92 and FY93 required that Draft Final Remedial Investigation/Feasibility Studies (RI/FS) for BRAC 88 bases on the National Priority List (NPL) be submitted to the Environmental Protection Agency (EPA) within 24 months. Draft Final RI/FSs for BRAC 92 bases on the NPL were to be submitted to the EPA within 36 months. It also provided a six month extension under certain conditions. It amended DBCRA 90 to clarify requirements of the Commission and to establish the BRAC account as the sole source of environmental restoration funding.[Ref. 5]

3. National Defense Authorization Act for Fiscal Year 1993 (NDAA 93)

The National Defense Authorization Act for FY93 amended BCRA 88 by delineating how the use of proceeds from the transfer or disposal of Commissary Stores and other facilities or properties could be used. It also provided funding for the Economic Development Administration (EDA) for economic adjustment assistance with respect to base closures.[Ref. 6]

4. National Defense Authorization Act for Fiscal Year 1994 (NDAA 94)

The National Defense Authorization Act for FY94 amended BCRA 88, DBCRA 90, and NDAA 92/93. It included the requirement for DOD to conduct personal and real property screening, gave authority to the Secretary of Defense to transfer governmental property to the local community at less than fair market value, required the Secretary of Defense to consider local and regional economic needs and priorities when considering transfer or disposal of real property in order to maximize the benefit from the reutilization and redevelopment of the closed military installation. The Act required DOD to be in compliance with the Stewart B. McKinney Homeless Assistance Act by providing to the Secretary for Housing and Urban Development a list of buildings that could be used to assist in the housing of homeless people. NDAA 94 required the Secretary of Defense to give priority to small and disadvantaged businesses when contracting services in support of base closure and realignment. Finally, NDAA 94 provided the Secretary of Defense the authority to designate a transition coordinator for each installation being closed to provide assistance to communities affected by the base closure.[Ref. 7]

5. National Defense Authorization Act for Fiscal Year 1995 (NDAA 95)

The National Defense Authorization Act for FY95 provided clarifying and technical amendments to previous acts. In an effort to promote rapid conversion of closed military installations, NDAA 95 provided authority to rent or lease governmental buildings to non-Federal entities. NDAA 95 required the Secretary of Defense to report to Congress the effects of a military closure on the ability of the Armed Forces to remobilize to pre-1987 levels if necessary and to detail any property disposed of that would be hard to reacquire if needed.[Ref. 8]

C. NATIONAL ENVIRONMENTAL POLICY ACT

The National Environmental Policy Act (NEPA) provided a process whereby federal officials would make decisions based upon an understanding of environmental consequences, and take appropriate actions to protect, restore, and enhance the environment during the process of closing or realigning a military installation. It also required DOD components to analyze potential environmental impacts of the proposed disposal action, including reasonably anticipated reuse activities, alternatives to the proposed disposal and reuse action, including the "no-action" alternative, adverse impacts, and any appropriate environmental impact mitigation actions. DOD components are required to ensure the environmental analysis is completed within 12 months of the Local Redevelopment Authority’s submission of its final reuse plan.[Ref. 9]

D. COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT (CERCLA)

The Comprehensive Environmental Response, Compensation, and Liability Act defines the roles of the Environmental Protection Agency (EPA), state agencies, and DOD components with respect to base closure and realignment. It requires the conduct of any needed response action when there is a release of a hazardous substance into the environment or there is a release of any pollutant or contaminant into the environment that may present an imminent and substantial danger to public health and welfare.

This Act, commonly referred to as Superfund, was enacted in December 1980. It created a tax that went to a trust fund for cleaning up abandoned or uncontrolled hazardous waste sites. It delineated two types of response actions on the part of affected parties: (1) short-term removals, where actions may be taken to address releases or threatened releases requiring prompt response, and (2) long-term remedial response actions, that permanently and significantly reduce the dangers associated with releases or threats of releases of hazardous substances that are serious, but not immediately life threatening on installations listed on the EPA’s National Priorities List.[Ref. 10]

E. ENDANGERED SPECIES ACT (ESA)

The Endangered Species Act, enacted in December 1973, required DOD components in partnership with the U.S. Fish and Wildlife Services to provide protection for threatened or endangered species by prohibiting activities and facilities that would have an adverse effect on species listed on the Endangered Species List (EDL). [Ref. 11]

F. DEPARTMENT OF DEFENSE DIRECTIVES

1. DOD Directive 4700.4, Natural Resources Management Program

The Natural Resources Management Program prescribes policies and procedures for an integrated program for the management of natural resources on DOD property. It established requirements for evaluating the relative risk posed by a site and for using the information for program planning and execution. It implemented a program to expedite the restoration and transfer of property at closing and realigning installations known as the Fast-Track Cleanup (FTC) program. As a goal, the program is intended to reduce, in the most cost-effective manner, the risks to human health and the environment resulting from past contamination at DOD installations. It designated the Under Secretary of Defense for Acquisition and Technology as the BRAC Environmental Restoration Program Decision Authority.[Ref. 12]

2. DOD Directive 4715.1, Defense Environmental Restoration Program (DERP)

For decades, DOD activities and industrial facilities generated, stored, recycled, and disposed of hazardous waste in ways which sooner or later contaminated nearby soil, groundwater, and surface water. In most instances, these activities predated existing environmental laws and regulations as well as modern methods of waste disposal and pollution prevention.

In 1984, DOD implemented the Defense Environmental Restoration Program (DERP) and appointed the Deputy Under Secretary of Defense (Environmental Security) as the program overseer and for the efficient allocation of funds for cleanup activities. The purpose of the DERP is to identify, assess, and cleanup or control hazardous waste contamination that originated from past DOD activities, operations or spills.[Ref. 13]

3. DOD Directive 4165.67, Revitalizing Base Closure Communities—Base Closure Community Assistance

Following several rounds of base closure, hundreds of military installations were closed in an effort to shrink DOD's infrastructure. Because a military base represents a major employment center and provides significant economic stimulus to the local economy, closing a base has the potential to cause catastrophic economic repercussions. DOD recognized that the manner in which real and personal property is transferred during a closing has grave implications on the local community's ability to recover economically.

In July 1993, President Clinton announced a plan to provide for more rapid redevelopment and job creation in communities affected by base closure decisions. It gave top priority to helping affected communities realize early reuse of base assets to spur economic recovery. In response to the President's actions, the Secretary of Defense implemented the Revitalizing Base Closure Communities—Base Closure Community Assistance Instruction. The intent of the instruction is to prescribe procedures for implementing base closure regulations and also help affected communities recover through effective reuse of base assets, rapid job generation, and cooperative accomplishment of mutual goals by all involved parties.[Ref. 14]

4. DOD Instruction 6055.9-STD, DOD Ammunition and Explosives Safety Standards

In August 1997, DOD established uniform safety standards for personnel and property involved in ammunition and explosives. It provided guidance for personnel and property protection from explosives and ammunition, specific guidance for personnel to limit exposure to explosives and ammunition, guidance for facility construction, and guidance for waiver approval where deemed necessary by the Component Commander.[Ref. 15]

5. DOD Directive 6055.14, Unexploded Ordnance (UXO) Safety On Ranges

In January 1998, the Department of Defense implemented the Unexploded Ordnance (UXO) Safety On Ranges Instruction after recognizing the need for a uniform policy to be utilized and recognized throughout the Military Services and also by other federal agencies. Traditionally, the Military Services governed themselves, but it was soon realized that there was no overarching DOD guidance for the service components to use as a baseline.

The Instruction designated the Under Secretary of Defense for Acquisition and Technology as being responsible for UXO explosives safety policies. The Instruction also required the clearance of UXO from ranges following a thorough risk assessment. It required DOD Components to establish education programs not only for installation personnel, but also for the surrounding community.

Finally, the Instruction directs DOD to take all necessary actions to protect personnel and property on and off military installations.[Ref. 16]

G. SUMMARY

Contamination of military installations with UXO is a problem that has been brought to the attention of the public following the initial rounds of BRAC. The potential safety hazards posed to local citizens has mandated that immediate action be taken by DOD to cleanup the hazard. Many agencies, federal, local, and defense-wide, have promulgated legislation and regulations to guide DOD in their efforts to clean up contaminated installations. This chapter discussed the legislation and regulations to provide a framework for later discussion of the actual process of UXO cleanup.

Chapter III discusses six phases of Non-Time-Critical Removal Action necessary for the proper cleanup of UXO. Each phase will be discussed, detailing the complexity of the process and how successful cleanup can be when executed correctly.

III. PHASES ASSOCIATED WITH A NON-TIME-CRITICAL REMOVAL ACTION (NTCRA)

Chapters I and II presented an introduction to the thesis research including a background of BRAC and the former Fort Ord Military Installation. A major problem facing military installations closed or transferred under one of the series of four BRAC legislations is that of UXO. UXO, left buried or hidden, poses many hazards to both the health of citizens and also to the environment. Because one of the objectives of Base Realignment and Closure is to transfer existing land to the local community for use and future economic development, DOD must first determine if a UXO problem exists and if so, how to clean it up prior to turning land over to civilian authority.

DOD, in conjunction with the EPA, has required that several actions take place prior to any environmental cleanup of UXO. These actions are grouped into four major categories: (1) site evaluation, (2) Engineering Evaluation/Cost Analysis, (3) removal action, and (4) closeout.[Ref. 17]

This chapter focuses on those Non-Time-Critical Removal Actions (NTCRA) in cases where there is not an imminent danger to public health or the environment and where there is at least six months time allowable prior to any actions having to take place.[Ref. 17] The standard phases of the NTCRA are illustrated in Figure 3-1. Each of these are discussed in the following sections.

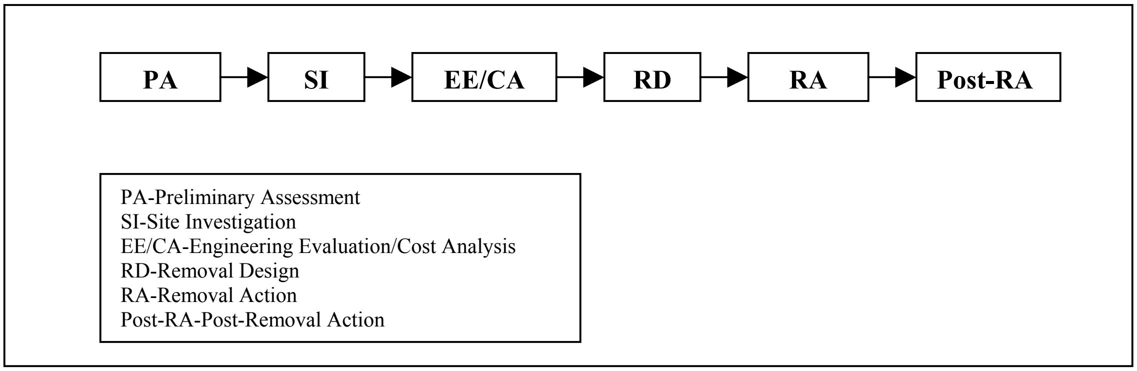

Figure 3-1. Non-Time-Critical Removal Action Process

A. PRELIMINARY ASSESSMENT

The first step in any potential cleanup process is a formal Preliminary Assessment (PA) to determine if a particular piece of land is contaminated with UXO and if so, the extent of the contamination.[Ref. 18] During a PA, information about a site is collected to evaluate the potential for release of a hazardous contaminant.[Ref. 18] Typical data collection includes a search of facility files, reference materials, interviews, local environmental surveys and site reconnaissance.[Ref. 19] In most cases, the EPA is responsible for conducting the PA, but in UXO cases that typically involve DOD installations, DOD is responsible for the PA and is to confer with the EPA as necessary, prior to its final submission of the PA to the EPA.

B. SITE INVESTIGATION

The second phase of the NTCRA, the Site Investigation (SI), is conducted when it is determined by the PA that further investigation is required. During this phase a comprehensive records folder of the site is opened known as the Archives Search Report (ASR). Information included in the ASR includes historical information, detailed interviews with knowledgeable personnel, aerial photos of the land area, and topography maps. Together these items are used to gain an understanding of the different types of ammunition used in training, the amount of ammunition used over the life of the range, and the amounts of UXO potentially present on the range. A preliminary risk assessment along with the ASR is used to estimate the extent of UXO hazard present.[Ref. 20]

C. ENGINEERING EVALUATION/COST ANALYSIS

The purpose of an Engineering Evaluating/Cost Analysis (EE/CA) is to evaluate the potential removal action alternatives for a given site. An EE/CA will provide alternatives that are designed to protect public health, recommend an appropriate removal action, and document the decision making process. The EE/CA also analyzes the removal action alternatives in terms of cost, effectiveness, and implementation ability. Once completed, the EE/CA is made available for public viewing and any arguments for or against the proposed action is documented an included as an addendum to the EE/CA. After the public response period, an Action Memorandum (AM) is drawn up detailing the final decision made by the BRAC cleanup committee.[Ref. 25]

D. REMOVAL DESIGN PLAN

Once the EE/CA has been finalized through the Action Memorandum process, a Removal Design (RD) plan is drawn up detailing the steps required that will achieve the UXO response objectives as outlined in the AM. Included in the plan are personnel qualifications, extent of cleanup, safety designs, and contract specifications. Also during this phase, the respective installation must submit an Explosive Safety Sheet to the DOD Explosives Safety Board (DDESB) outlining their plan to ensure the safety of all involved. The mission of the DDESB is to provide objective advice to the Secretary of Defense (SECDEF) and Service Secretaries on matters concerning explosives safety and to prevent hazardous conditions to life and property on and off DOD installations from the explosives and environmental effects of DOD munitions.[Ref. 20]

E. REMOVAL ACTION

During this phase, actual implementation of the Removal Design Plan takes place. Actions included in this phase can range from detonation and cleanup in place to removal and detonation off-site. Also included during this phase are land clearance and excavation required to search and remove the hazard.[Ref. 20]

F. POST-REMOVAL ACTION

The final phase of the UXO process is the Post-Removal Action (Post-RA) phase. This phase is not a required phase, but more of a precautionary phase. Actions in it include public education of the completed cleanup process, validation UXO sweeps, long-term monitoring, restrictions on the use of the land, and any further actions required if the use of the land changes.[Ref. 20]

G. SUMMARY

Chapter III provides a look at the phases associated with a Non-Time-Critical Removal Action (NTCRA), which pertains to the majority of UXO removals of facilities closed or realigned due to the BRAC process. The NTCRA process includes phases of study, sampling, research, analysis, removal actions, and post-removal after care. Chapter III addressed key aspects of each phase and also illustrated the process from its inception to its ending.

Chapter IV presents a list of the major participants in the UXO cleanup process and describes the roles that they play with respect to the former Fort Ord Installation.

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IV. MAJOR PLAYERS AND THEIR ROLES AT THE FORMER FORT ORD

In Chapter III, six phases of Non-Time-Critical Removal Actions (NTCRA) were discussed. To ensure a permanent solution is achieved in these situations, each phase of the NTCRA is a crucial element in the program's overall success.

As stated in this thesis, one of the reasons for ensuring a thorough cleanup is so that the land can be turned over to civilian municipalities for future development and use. Associated with this development and use are enormous economic benefits for not only the local communities but also the State as a whole.

Several key federal and statewide agencies have a vested interest in the cleanup process due to the overarching interests associated with the land and the UXO hazard. Thus, they play key roles in ensuring that the cleanup is performed safely, thoroughly, and expeditiously. This chapter lists those key agencies and provides a description of their roles in the overall cleanup process.

A. DEPARTMENT OF DEFENSE

The Department of Defense plays the role as the startup catalyst in the cleanup of UXO at installations listed on a BRAC list. Once a base has been approved for closure or realignment, DOD's Office of Environmental Cleanup (OEC) gets involved. OEC is charged with developing policy and overseeing Defense Environmental Restoration Program (DERP). As acknowledged in their mission statement, "Our mission is to protect the environment while reducing risks to U.S. troops, their families, and local communities from pollutants due to past practices". OEC also provides guidance and direction to DOD components, sets and measures performance standards, and promotes cost-effective and safe methods to protect the environment and human lives. One of the key ways OEC achieves its mission is through the use of extensive UXO training given to a variety of people from on-site technicians to local community leaders.[Ref. 21]

B. UNITED STATES ARMY CORPS OF ENGINEERS

The United States Army Corps of Engineers (USACE) Environmental Division, Directorate of Military Programs (CEMP-R) is responsible for developing, disseminating, and coordinating USACE policy and procedures involved in UXO cleanup. Other responsibilities include providing direction, guidance, and work assignments to personnel supporting UXO cleanup missions. They coordinate policy and program issues with other DOD and civilian organizations. USACE also appoints Program Managers (PM) to administer all phases of the UXO cleanup project to include Preliminary Assessments, real estate functions, Community Relations Plans, maintenance of Administrative Records, coordination with state and federal agencies to obtain environmental and historical documentation, and contract acquisition planning and execution. Partnerships are formed with other agencies, especially the United States Environmental Protection Agency, to facilitate coordination across multiple jurisdictions.[Ref. 22]

C. UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

The U.S. Environmental Protection Agency (EPA) is represented in UXO cases through its Federal Facilities

Branch Department of Defense Section. At DOD sites, EPA Remedial Project Managers (RPM) oversee all environmental cleanups of past hazardous materials including UXO. The RPM's primary role is to ensure DOD components adhere to all federal environmental laws and provide any assistance they may require.

The DOD Section further breaks itself down into two teams: (1) active and non-military installations and (2) military installations falling under BRAC authority. An internal/external partnering concept is instituted to facilitate open communication and information sharing among the EPA, States, and Federal Facilities. EPA has found that partnering enhances and expedites cleanup activities and provides a medium for technology information sharing.[Ref. 23]

D. CALIFORNIA DEPARTMENT OF TOXIC SUBSTANCES CONTROL

The California Environmental Protection Agency (Cal/EPA) plays a major role in the cleanup efforts at the former Fort Ord Installation. Their Office of Military Facilities within the Department of Toxic Substances Control (DTSC) provides regulatory oversight to the military organizations during their cleanup efforts. The Cal/EPA works directly with DOD and the US EPA to ensure the cleanup meets all environmental regulations. Cal/EPA also provides a public participation specialist to each base to provide the local community with fact sheets, organize community meetings, and answer any questions that arise concerning the cleanup process.[Ref. 24]

E. SUMMARY

Chapter IV presented some of the key agencies having regulatory oversight in the cleanup process of UXO at DOD installations. Because of the overlapping regulatory authority associated with BRAC facilities, this chapter presented DOD, Federal, and State regulatory agencies along with some of the roles and responsibilities they carry.

One of the major obstacles faced by workers participating in UXO cleanup are the various levels of vegetation that hide, mask, or cover up UXO. Chapter V provides a list of the seven common vegetation clearance methods and the pros and cons of each method.

V. METHODS OF VEGETATION CLEARANCE AND THEIR PROS AND CONS

When the Department of Defense first initiated Base Realignment and Closure (BRAC) procedures, one of the key elements needing to be accomplished was that of environmental cleanup. Federal and State laws as outlined in previous chapters required DOD to take specific actions to ensure all military installations were free from the hazards of UXO prior to their turnover to local communities.

Many of the explosive munitions left behind from years of training are very sensitive and can be detonated by simply bumping the munitions. Within the California region alone, several UXO explosive accidents have occurred to the civilian population since the BRAC process has begun.
[Ref. 26].

Highly explosive munitions cannot be safely removed by trained UXO personnel on many of the former installations due to the heavy vegetation that has accumulated on the closed ranges. Workers must be able to see the ground that they are walking and working on to avoid any accidental detonations to personnel and equipment.

Within the demining industry, there are seven alternative methods that are approved by DOD, EPA, and State and Local environmental agencies for the safe removal of UXO. The following alternative vegetation clearance methods will be discussed in this chapter along with pros and cons of each method: (1) no-action, (2) manual cutting,

(3) mechanical cutting, (4) remote cutting, (5) prescribed burning, (6) animal grazing, and (7) herbicides.

A. NO-ACTION

The first alternative, obviously, does not result in the clearance of vegetation, none-the-less it is an alternative method that is given equal weight among all methods.

This method is used when the realigned or transferred land will not be used for any economic development and can easily be fenced off or quarantined from public access. In this case, the Defense Component would not remove vegetation located on the land and any UXO would remain in place. This decision is justified by the past use of the land, early study and probability analysis of the existence of UXO on the land, and the assurance of no future economic use of the land by the receiving authorities. In most cases, these lands would be designated as wildlife habitat reserves by the local environmental agency.[Ref. 27]

B. MANUAL CUTTING

This method involves hands-on vegetation clearance through the use of chain saws, loppers, power chippers, weed-eaters, and any other non-motorized hand tool. The process involves a team of workers cutting away visible vegetation and shrubbery to a level that allows UXO workers to see the surface ground. It also may involve pruning trees to a level that produces an “umbrella” effect that will allow a worker to go underneath and view the surrounding ground.

A pro to using this method is that it is good for areas that are hard to reach using mechanical methods such as on sloped or rocky land. Another pro is that it produces little to no air emissions into the environment.

The cons though outweigh the pros in this case. The major problem with this method is that it exposes workers to sensitive explosives as they work. The risk of accidental detonation using this method is extremely high. Also, the time it takes to clear the vegetation using this method is much longer than some of the other methods to be discussed. On average it takes a team of six workers one day to cover two acres of land. Areas of significant amounts of land could easily take months to complete. Finally, use of this method could possibly violate environmental laws such as the Endangered Species Act or local habitat management laws.[Ref. 27]

C. MECHANICAL CUTTING

Mechanical cutting involves using commercial heavy equipment or trucks to pull or tow cutting machinery through the selected area. Like the previous method, this too will expose workers to UXO though there could possibly be some protection afforded to them from the towing equipment. If known armor-piercing munitions have been fired in this area, it could nullify the protection afforded by the towing equipment.

A pro to using this method is that a larger amount of land coverage can be achieved, though not significantly more than the manual method. On average a removal team could cover only 2.5 acres per day using this method. Similar to the manual method, at this rate, it would take several months of full-time work before large land areas would be cleared sufficiently for remedial removal action to take place. Another pro is that some mechanized equipment can be used on sloped terrain depending on the level of incline/decline and the thickness of the brush.

The cons also outweigh the pros in this alternative. Significant risks to human lives exist if accidental detonation should occur. Crews would have to proceed extraordinarily cautiously to minimize the risk, which could also lengthen the time required to successfully remove the vegetation. Also, many types of the mechanized equipment present air and noise emission hazards that could potentially increase the workers' chances of an accident. Mechanized equipment, in many cases, is limited in the size of vegetation growth that it can cut. Workers would have to be aware of the areas they are working in and ensure the correct equipment is on-hand for use. This would mean that various types of mechanical equipment would be required at the site, whenever needed, possibly increasing the cost of the clearance. This method also has the potential for violating federal and local environmental laws depending on the vegetation being cleared since it cannot discriminate between various types.[Ref. 27]

D. REMOTE CUTTING

Remote cutting involves the use of remote controlled mechanical cutting equipment as described in the preceding paragraph. Although this sounds like an ideal technological breakthrough in vegetation clearance, the actual product remains in the research and developmental stage. Several companies are currently experimenting with remote units that can allow the worker to operate at distances as close as 100 feet and as far away as 3000 feet. Depending on the distance, some have experimented with the use of video surveillance cameras mounted to the cutting equipment that allow the worker to maintain the safest distance possible.

The most positive feature to this method is the safety it affords the worker by allowing him to work at greater distances away from the clearance site. If an accidental detonation should occur, the maximum safe operating distance reduces the worker’s chances of injury.

Unfortunately, working with remote control devices will slow the clearing process somewhat. Depending on the worker’s skill level, actual clearance times could vary, but on average would be only 2 acres per day. As in the previous paragraph concerning mechanical equipment, accidental detonation has the potential to damage the cutting equipment and the probability of occurrence increases the farther away the operator is from the equipment since he cannot see any dangers surrounding the equipment. Using a surveillance camera could also decrease the field of vision for the worker, which increases the potential of overlooking a piece of UXO. Damage to equipment could also put workers at risk if it becomes necessary for them to enter the site to repair the equipment. Accidental detonation in this case increases each time they have to enter UXO areas.

Considering the decreased risk to human lives associated with this method and the number of future vegetation clearance operations that can occur as more installations are closed or realigned, it would be a worthwhile venture for DOD to partner with industry through research and development to expedite the development and production of remote cutting equipment.[Ref. 27]

E. PRESCRIBED BURNING

The quickest method to use in vegetation clearance operations is prescribed burning. In prescribed burning, land areas are carefully set on fire and allowed to burn by highly trained forestry firefighting crews. Prior to the burn, a meteorologist would conduct a climatologic analysis, to determine a window of opportunity in which specific climate conditions would allow for a safe burn. Also, a pre-burn process must be conducted to prepare the vegetation for a more complete burn by either using a mechanical crushing process or by herbicidal application. The actual burn itself would be conducted aerially via helicopter as a small number of personnel remain outside the burn area to coordinate the efforts.

The time required to conduct a burn is by far its greatest selling point. Within a week’s time frame, an entire range site consisting of thousands of acres could be cleared leaving a clear view of the land for UXO workers to begin the removal process. In almost all cases, prescribe burning reduces the vegetation to the bare ground with minimum exposure to workers. The only instance in which possible exposure could occur to workers on the ground is during the pre-burn process in which mechanical crushing is used. To avoid this risk, aerial herbicidal application could be chosen. Another positive aspect concerning prescribed burning is that the vegetation tends to respond well to the burning and enhances its future restoration process. A well-coordinated and controlled burn tends also to fall within standards of all applicable environmental laws including air emission standards and is the method of choice by the U.S. Fish & Wildlife Service.[Ref. 28]

Harmful air emissions from a prescribed burn are undoubtedly one of the major setbacks to this method. As with all fires, large amounts of smoke will be emitted into the air. That has the potential to cause harm to the public especially in areas where plants such as poison oak are located. In most cases, many precautions are taken to minimize the amount of smoke given off during and after the burn process and the amount of harm caused to the surrounding community such as burning on certain climatologically safe days to providing housing accommodations to nearby residents who are adverse to the smoke.[Ref. 27]

F. ANIMAL GRAZING

This method of vegetation clearance involves introduction of animals, normally goats, into the land site allowing the animals to eat the vegetation until complete clearance is accomplished. To control the goats, electrically charged fencing is installed to restrict the herd of goats in defined areas. Temporary shelter would need to be installed for the sheepherders and also trained herding dogs to assist with the sheep.

When considering this option, the only pro argument is the low cost to complete the clearance using this method.

The cons greatly outweigh the pros. The length of time required for goats to successfully clear the land of vegetation to a visually acceptable level for UXO workers to come in would be months if not years. Also the risk of accidental detonation to the animals and herders increase significantly with this method. Goats are also limited in the height of vegetation, which they can reach. Vegetation greater than 4 feet would have to be cleared by another method.

Even though animal grazing is an acceptable form of vegetation clearance throughout the world, it has not been used as an actual method of vegetation clearance where explosive hazards are present. The likelihood of protests from animal rights activist increases significantly because of the lethal hazards to which the animals are exposed.[Ref. 27]

G. HERBICIDES

The use of herbicides to clear vegetation is the final method. Herbicides destroy vegetation by either retarding the growth for a short period or a more permanent destruction of the plant life for a period of several years. Using various dispersion methods from aerial spraying via helicopter to truck mounted sprayers to shoulder carried containers manually sprayed on foot in constrained areas, herbicides can be applied within a few weeks varying with the size of the site.

The ability of an aircraft to cover large areas of land provides a positive aspect to this method. The time required to spray a typical range of several thousand square feet would be about one week but the length of time required before the vegetation itself is destroyed varies significantly.

The most negative aspect of this method is the introduction of potentially harmful herbicides into the environment. Because the herbicides are most economically sprayed using aerial spraying, the potential for areas outside of the designated UXO area to be covered with herbicides increases. The potential for exposure to humans is minimal within the UXO area, but could potentially spread into the surrounding community if unfavorable wind conditions exist. Also, herbicides could potentially harm rare species of plants and animals and may not be a viable option based upon existing environmental laws.[Ref. 27]

H. SUMMARY

To facilitate investigation and removal of UXO from Former Military Installations, vegetation clearance is required to allow workers to safely see the area they are working on. Vegetation clearance consists of removal of standing top growth down to the bare ground. Because of the innumerable sizes of growth encountered, various clearance methods have been discussed in this chapter.

Methods have ranged from doing nothing or taking no-action to inserting live animals into designated areas to consume the plant life. This chapter provided a general overview of the process associated with each method and also provided some of the pros and cons of each alternative.

Of all the methods, prescribed burning appears to be the best option but it may require herbicides in areas unable to be burned. It has the shortest completion time, the results are demonstrated within a matter of days, any rare or endangered plant habitat are more likely to recover with minimal damage, and it is the most favored method used by the U.S. Department of Fish and Wildlife Services. However, prescribed burning does produce significant harmful emissions into the air and poses a potential danger to any nearby residents. Site management can manage prescribed burning effectively if all necessary precautions are taken to eliminate its harmful effects.[Ref. 28]

Chapter VI presents a cost estimation model using a mathematical analysis tool known as regression analysis. The resulting model is created using historical cost data from previous cleanups. Finally, Chapter VI discusses the current cost estimate program used by DOD and provides a comparison between the created model and the DOD model.

VI. DATA DESCRIPTION AND COST ESTIMATE MODEL

The primary thesis objective is the development of a comprehensive and serviceable cost model for estimating cleanup costs of Unexploded Ordnance at Department of Defense installations being considered for closure or realignment.

This chapter consists of a description of the data collected, which are used to build the cost model. An overview of regression analysis is discussed along with tables and figures describing the outcome of the regression process. Section D compares this model with cleanup cost estimates taken from sites at the former Fort Ord. Finally, Section E summarizes the chapter highlights.

A. DESCRIPTION OF DATA

Research data collection encompassed cost data of environmental cleanups of UXO from various sites at the former Fort Ord. The compiled data were configured to build the most viable mathematical cost estimation model given the available data.

For purposes of model development, a total of 20 sites located throughout the installation were selected based upon available historical data. Within these 20 sites, 6 different explanatory variables were chosen to build the initial regression model to be explained below. The 20 sites chosen for model formulation are listed in Table 6-1.

CLEANUP SITES	
OE-44	OE-10A
OE-10B	OE-11
OE-35	OE-54
OE-15(R&T)	OE-53
OE-15(SEASIDE)	OE-21
HTW	OE-13B
OE-55	LATRINE PITS
FUEL BREAKS	OE-32C
OE-42	OE-45
OE-14D	OE-23

Table 6-1. Fort Ord Sites Employed in Regression Model

Data for the dependent and independent variables were derived from information provided by USA Environmental, Incorporated, an UXO contractor hired by the United States Army Corp of Engineers (USACE), as Ordnance and Explosives Removal After Action Reports. Each independent or explanatory variable shown in Table 6-2 was applied in numerous analyses to determine the best model.

Symbol	Independent Variable	Quantitative /Categorical
MH	Number of Man Hours Worked	Quantitative
VCM	Method of Vegetation Clearance	Categorical
SW	Scrap Weight	Quantitative
SE	Special Equipment Required	Categorical
NUXO	Number of UXO Recovered	Quantitative
SE/NUXO	Special Equip./Number of UXO	Quantitative

Table 6-2. Independent Variables Used in Regression Model

A comprehensive examination of each After Action Report provided extensive information used to form causal relationships for the overall cost of the cleanup. Careful consideration was given to many different variables that could have been chosen, but only six appeared to provide some form of relationship to the overall cleanup cost at each site. The six variables shown in Table 6-2 are described below:

MH. This quantitative variable consists of the Total Number of Man Hours expended on the cleanup project including project management personnel, on-site cleanup technicians and supervisors, administrative personnel, and logistics personnel. It became very intuitive that labor related activities were a major driver of costs involved in any cleanup project.

VCM. This categorical variable was chosen based upon information presented earlier in this thesis that described the preliminary requirements for on-site UXO personnel to have a clear visual field of the ground to be worked upon to minimize risks to personnel and equipment during the cleanup process. Based upon the data, five categories were chosen to describe the vegetation clearance method utilized at each site including a “no clearance required” category. A categorical number from 1-5 was given to each method or combination of methods as shown in Table 6-3 to describe the method utilized at each site. For example, if a site required the use of both manual and mechanical vegetation clearance methods, that site would be assigned a 4 for that category.

Vegetation Clearance Method Identification Table
1-None
2-Manual
3-Mechanical
4-Manual and Mechanical Combined
5-Prescibed Burn, Manual, and Mechanical Combined

Table 6-3. Vegetation Clearance Methods

SW. This quantitative variable consists of the total weight in pounds of either OE related scrap, which are pieces of ordnance material that are the result of ammunition firings, or non-OE related scrap, which are metallic items found during cleanup such as cans, pipes, target parts, etc. Because on-site labor costs increase as personnel spend more time on the site, any time spent recovering scrap has a positive effect on overall costs.

SE. In many cases, but not all, special equipment is needed to support the cleanup of UXO. This categorical variable takes into consideration the positive effect special equipment would have on overall costs if utilized. A value of 1 is given if special equipment was used and 2 if no special equipment was used.

NUXO. This quantitative variable is simply the total number of UXO items recovered at a particular site. Because the completion of the cleanup is dependent on the time required to recover all UXO at a site, this variable has a positive effect on the time spent at the site and thus on the overall cost.

SE/NUXO. This variable was chosen to solve a correlation problem between the two separate variables. The problem of correlation exists due to the fact that the number of UXO items recovered is affected by whether special equipment is utilized to speed up and enhance the overall process. By combining the two variables, the model is able to capture the overall effect upon total cost without having to drop one of the variables from the model.

In this model, the only dependent variable utilized is Total Cost ($TC), which is required to complete the respective UXO cleanup project. Thus, the independent variables in the final selection model will attempt to explain the variables' relationship to the dependent variable, Total Cost.

B. REGRESSION ANALYSIS OVERVIEW

Regression Analysis is a modeling technique for analyzing the relationship between a continuous dependent variable and one or more independent variables. Regression is one of the most widely used quantitative techniques in business and governmental organizations.[Ref. 29]

The goal in regression analysis is to identify a mathematical model or function that describes, as closely as possible, the relationship between a set of independent variables and a dependent variable so that one can predict what value the dependent variable will assume given specific values for the independent variables. The multiple regression output is an algebraic model depicting an equation for the expected value for the dependent variable given specific values for the explanatory variables. The typical multiple regression equation is as follows:

$$Y_c = a + b_1X_1 + b_2X_2 + \ldots + b_mX_m$$

where,

Y_c= the estimated Y value from the regression equation in which $X_1, \ldots X_m$ are the independent variables;

a= a constant variable or the linear intercept;

b_i= the coefficient of X_1 in the regression equation in which other b values are in the equation;

X_m= the independent variables

In simple regression, the least-squares method is used to fit a straight line to the sample of observations in a manner that minimizes the sum of the squared errors of each observation from the line. Multiple regression is similar to simple regression, except that a plane is used to fit the sample observation points.
[Ref. 30]

In order to evaluate the effectiveness of the resultant regression equation, we must have a way of determining how well the line fits our actual data. To determine the goodness of fit, statisticians typically use the following four measures:

R^2 Statistic. The R^2 statistic, also referred to as the coefficient of determination, is a value that ranges from 0 to 1 and indicates the proportion of the total variation in the dependent variable around its mean that is accounted for by the independent variables in the regression function. The higher the percentage value, the greater explanatory value of the independent variables.

t-ratio (T). The t-ratio simply refers to the number of standard errors of the regression coefficient. When looking at the t-ratio, one is trying to determine if the slope is significantly different from zero. So, the higher the t-ratio, the more important the variable is in explaining the dependent variable. Typically, a value greater than +/- 2 is acceptable given an accompanying p-value greater than .1 significance. A p-value is simply 1 minus the probability that a given situation would occur. This is achieved by subtracting the given p-value from 1 to yield the actual percentage value. For example, a p-value of .001 says that the associated t-ratio is 99.9% accurate.

f-ratio (F). The f-ratio is another alternative approach for testing whether the slope of a regression equation is statistically significant. The f-ratio is the ratio of the variance that is due to the regression divided by the error variance.

Standard Error of Estimate (S). A measure of the accuracy of the prediction obtained from a regression model is given by the standard deviation of the estimation errors. The Standard Error measures the amount of scatter, or variation, in the actual data around the fitted regression function. A smaller Standard Error value is considered superior to a higher value.[Ref. 30]

C. ANALYSIS OF REGRESSION OUTCOME

This subparagraph details the multiple regression statistical results along with graphical presentations of the outcome. The multiple regression computations and analytical tests were performed using the commercially produced MINITAB Statistical Analysis software package.[Ref. 31] The data and graphical representations displayed are outputs of the MINITAB system. A discussion of the basic assumptions related to the error terms are required in order to test the goodness of fit of the regression equation.

Figure 6-1 displays a histogram, which represents the distribution of the dependent values, utilized in the model.

```
Histogram of Total Cost N = 20
Midpoint          Count
      0-49999      6  ******
 500000-999999     9  *********
1000000-1499999    1  *
1500000-1999999    1  *
2000000-2499999    1  *
2500000-2999999    0
3000000-higher     2  **
```

Figure 6-1. Distribution of the Dependent Variable Total Cost ($TC)

When analyzing a histogram, one looks for a distribution of data that resembles the shape of a bell. This bell shaped curve is considered to be symmetric meaning that if a mirror were placed down the middle of the bell, both sides would be equal in appearance. As seen, the Total Cost distribution is skewed towards or leaning more towards the lower values. In order for the distribution to be more approximately symmetric or equal in appearance, a transformation must be performed to each of the dependent input values in column $TC of Table 6-6.

There are three alternative ways that the dependent variable can be transformed to make it more approximately symmetric. Table 6-4 presents each alternative procedure along with the effective strength it has on the transformation of the dependent variable.

Transformation	**Strength**	**Formula**
Square Root	Moderate	SQRT(Y)
Logarithm (base 10)	Strong	$\log_{10}(Y)$
Negative Reciprocal	Stronger	-1/Y

Table 6-4. Three Transformations of Y Variable

Figure 6-2 presents the distribution of Total Cost after undergoing square root transformation. The distribution is now more symmetrical or bell shaped in appearance providing data that are normally distributed. Transformation using the other methods did not produce the desired symmetry and were not viable solutions.

```
Histogram of C3   N = 20
Midpoint           Count
   0- 199            1  *
 200- 399            4  ****
 400- 599            1  *
 600- 799            5  *****
 800- 999            4  ****
1200-1399            2  **
1400-1599            1  *
1600-1799            1  *
1800-higher          1  *
```

Figure 6-2. Distribution of the Transformed Dependent Variable Total Cost ($TC)

One of the necessary conditions that must be satisfied for regression analysis to accurately demonstrate the cause and effect relationship between independent variables and a dependent variable is that independent variables are not perfectly related to each other. There are several ways to measure the association between variables. The most common measure is the Pearson product moment correlation coefficient. Figure 6-3 presents the Pearson correlation matrix of the five single independent variables. The correlation coefficient is always between –1 and +1. If there is almost no association between the independent variables, the resulting value will be near 0. Highly related variables will approach +1 if a positive relationship is found or –1 if a negative relationship exists. A general rule to follow is, if any two variables produce a coefficient of more than .7, a multicollinearity problem could possibly exist between the two variables.

	MH	NUXO	VCM	SE
NUXO	0.619			
	0.004			
VCM	0.349	-0.138		
	0.132	0.561		
SE	-0.126	0.299	-0.709	
	0.597	0.200	0.000	
SW	0.931	0.711	0.176	-0.028
	0.000	0.000	0.457	0.906

Cell Contents: Pearson correlation (top)
P-Value (bottom)

Figure 6-3. Correlation Matrix of Single Independent Variables

This means that because the variables are so closely related, the regression model would be unable to explain which variable has the greatest effect on the dependent variable. In Figure 6-3, MH and SW were highly correlated with a Pearson correlation of .931. In cases like this, one of the variables would either have to be eliminated or a ratio/composite variable would have to be created. The variable, Scrap Weight, was eliminated producing the correlation matrix in Figure 6-4.

	MH	NUXO	VCM
NUXO	0.619		
	0.004		
VCM	0.349	-0.138	
	0.132	0.561	
SE	-0.126	0.299	-0.709
	0.597	0.200	0.000

Cell Contents: Pearson correlation (top)
P-Value (bottom)

Figure 6-4. Four Variable Correlation Matrix

Figure 6-4 presents the four variable correlation coefficient matrix after eliminating the independent variable scrap weight. No positive correlation exists between the four variables and thus they may be included as potential variables in the regression model.

Now that the selection of the independent variables is complete, regression analysis can begin using the four variables MH, NUXO, VCM, and SE. The initial step in regression requires running an analysis using all possible variables. Using the goodness of fit measures, each variable's t-ratio is evaluated. Independent variables that have t-ratio's below 1.0 are either eliminated or combined with another variable to capture the effect it has on the dependent variable. Having made several runs, a new independent variable was created by dividing SE/UXO due to both variables having low t-ratios independently. Figure 6-5 presents the final analysis output resulting in three independent variables that explain 93.3% of the overall cost associated with cleanup of UXO.

The regression equation generated in Figure 6-5 says that the sqrt($TC) = 262 + 0.0172(MH) + 67.2(VCM) - 97.1 (SE/UXO). Once this number is generated, it will have to be transformed back into a standard numerical dollar figure by squaring its value. These variables have been selected as part of the final model equation because each has a t-ratio greater than or near 2.0 with accompanying p-value confidence levels between 90.9%-99.9%.

Looking at the other goodness of fit measures, the analysis yields an R^2 value of 93.3% which says that the regression equation explains 93.3% of the variation in the dependent variable. The f-ratio of 74.05 is the ratio of the explained variation over the unexplained variation. This information is used to indicate whether or not the overall regression equation is significant which in this case has a p-value with a confidence level of 99.9%. Finally, the standard error of 139.0 says that 95% of the data points fall within a range of +/- 274.0 around the regression line. This number is rather high and could potentially provide an explanation if the final outcomes of the model are significantly different from Actual Total Cost values.

The regression equation is:
sqrt($TC) = 262 + 0.0172 MH + 67.2 VCM - 97.1 SE/UXO.

Predictor	Coef	SE Coef	T	P
Constant	262.38	98.52	2.66	0.017
MH	0.017215	0.001515	11.36	0.000
VCM	67.23	27.95	2.41	0.029
SE/UXO	-97.10	53.96	-1.80	0.091

S = 139.0 R-Sq = 93.3% R-Sq(adj) = 92.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	4292946	1430982	74.05	0.000
Residual Error	16	309189	19324		
Total	19	4602136			

No replicates. Cannot do pure error test.

Source	DF	Seq SS
Man Hrs	1	3945536
Veg Clea	1	284835
UXO/S.E.	1	62575

Unusual Observations

Obs	Man Hrs	logt(c2)	Fit	SE Fit	Residual	St Resid
9	7014	828.3	514.4	51.1	313.9	2.43R

R denotes an observation with a large standardized residual
Durbin-Watson statistic = 2.44

Figure 6-5. Multiple Regression Analysis for sqrt($TC) versus MH, VCM, SE/UXO

One additional piece of information that can be retrieved from the analysis output is the Durbin-Watson statistic test of 2.44. One assumption of regression is that each error term value is independent of those values coming before and after it. The Durbin-Watson test is a statistical test for the summary measure of the amount of correlation in the error terms. Uncorrelated errors will fall within a range of 1.36 to 2.64 with 2 being the center value. In other words, the closer the value is to 2 the greater confidence we have that the errors are not correlated or positively related to one another.[Ref. 31]

Figure 6-6 presents a graph of the residual errors versus the Fit or estimated value of the dependent variable. When analyzing the graph, one expects no pattern or special order in which the data falls on the graph. In other words, the user wants to see that the points are randomly distributed throughout the graph in no set order.

```
 3.0+
        -
Errors  -              *
        -
        -
     1.5+
        -                  *
        -               *    *                  *
        -  *               *             *
        -
     0.0+  *  *                                                  *
        -                *   *                                 *
        -
        -                  *   *
        -     *        *                            *
    -1.5+        *
        -
          ------+---------+---------+---------+---------+---------+Yc
               300      600      900       1200      1500      1800
```

Figure 6-6. Residual vs. Fit Plot

Two regression assumptions being tested by the Residual versus Fit plot are Linearity and Homoscedasticity. One of the first assumptions in regression analysis is that the dependent variable is linearly related to each of the independent or explanatory variables. If one tries to force a linear relationship to exist when a non-linear relationship exists, the residual vs. fit plot will clearly demonstrate this by allowing the distribution of values to fall in a set pattern rather than randomly. A second assumption is that the error terms all have a constant, specific or finite variance, so no one distribution is more spread out than another about the regression line. If the error terms are not evenly distributed, then a pattern would emerge on the residual vs. fit plot.

Figure 6-7 presents a graph of the error terms versus the normal scores of the error terms or what is referred to in the statistical world as the normal probability plot.

```
3.0+
         -
 Errors  -                                                        *
         -
         -
      1.5+
         -                                                 *
         -                                        * *  *
         -                                 * * *
         -
      0.0+                            * * *
         -                       * **
         -
         -                  *  *
         -         *   *  *
     -1.5+  *
         -
           --------+---------+---------+---------+---------+------Nscore
               -1.40     -0.70      0.00      0.70      1.40
```

Figure 6-7. Normal Probability Plot

To test the assumption of normality of the error terms, the normal scores of the error terms are calculated. The normal scores are values that resemble a standard probability distribution. Thus, if the error terms are perfectly normal in distribution, then a plot of the error terms versus the normal score should show a rough 45-degree straight line. As seen in Figure 6-7, the plot does present a rough 45-degree straight line and the normality assumption is met.

D. COMPARISON OF MATHEMATICAL MODEL ESTIMATES VS. FORMER FORT ORD ESTIMATES

The purpose of this section is to compare the former Fort Ord estimates with the regression model's Total Cost forecast. Utilizing a spreadsheet program such as Microsoft's Excel™, model forecast estimates using the regression equation might be found. Table 6-5 displays the dependent and independent variables, transformed dependent variable, error, fit, and normal score values, model square root values (Model sqrt($TC)), and finally, model Total Cost values(Model $TC).

The Model sqrt($TC) column displays the square root values produced using the regression equation. Squaring the Model sqrt($TC) values produces an estimated cost for the 20 sites as displayed in the Model ($TC) column.

To validate the accuracy and effectiveness of the developed model estimation tool using regression analysis, 5 of the 20 sites provided DOD model estimates in the available After Action Reports and are chosen for comparative analysis.

SITE	$TC	Model ($TC)	sqrt ($TC)	Model sqrt($TC)	MH	VCM	SE/UXO	Errors	Yc	Nscore
OE-44	407543	553984	638.3909	744.3011	8803	5	0.0526	-0.8677	744.9803	-0.5895
OE-10B	1229128	1079938	1108.6605	1039.2005	25679	5	0.0049	0.5433	1040.1330	0.3146
OE-35	3995	54640	63.2060	233.7512	96	1	1.0000	-1.3342	234.1700	-1.4034
OE-15(R&T)	496724	398090	704.7865	630.9436	13649	2	0.0023	0.5646	631.5949	0.4478
OE-15(SEA)	677704	494738	823.2278	703.3760	10075	4	0.0074	0.9063	704.0406	1.1281
HTW	275094	336084	524.4940	579.7277	6770	3	0.0033	-0.4207	580.3092	-0.3146
OE-55	598808	394886	773.8269	628.3995	9619	3	0.0067	1.0862	629.0237	1.4034
FUEL BRKS	396932	470674	630.0254	686.0568	9040	4	0.0024	-0.4319	686.7058	-0.4478
OE-42	686042	264049	828.2765	513.8572	7014	2	0.0328	2.4282	514.4089	1.8682
OE-14D	2773860	2883106	1665.4909	1697.9710	75673	2	0.0000	-0.3595	1699.5540	-0.1868
OE-10A	1843541	1583777	1357.7706	1258.4820	38422	5	0.0039	0.7851	1259.6060	0.7441
OE-11	406531	285298	637.5978	534.1333	8602	2	0.1053	0.7886	534.7093	0.9191
OE-54	135854	261535	368.5838	511.4052	3093	3	0.0556	-1.0848	511.9316	-0.9191
OE-53	3133830	3088802	1770.2627	1757.4987	71324	4	0.0008	0.0997	1759.0834	0.0619
OE-21	26155	114102	161.7251	337.7895	589	1	0.0159	-1.5031	338.2112	-1.8682
OE-13B	1493362	1878585	1222.0319	1370.6149	48836	4	0.0017	-1.1731	1371.8618	-1.1281
LATRINES	58487	25323	241.8409	159.1316	1403	1	2.0000	0.7125	159.5747	0.5895
OE-32C	17130	20213	130.8816	142.1724	417	1	2.0000	-0.1014	142.6007	-0.0619
OE-45	265795	409880	515.5531	640.2187	6832	4	0.0833	-0.9577	640.8350	-0.7441
OE-23	59843	51733	244.6283	227.4496	1468	2	2.0000	0.1477	227.9272	0.1868

Table 6-5. Model Estimate Worksheet

Table 6-6 displays the former Fort Ord's cleanup cost estimate, the developed model estimate, Actual Total Cost, and finally comparative variances between the data. For 4 out of 5 sites, the former Fort Ord Budgeted Cost of Work Performed (BCWP) were within $1,000 of Actual Cost of Work Performed (ACWP) and in all but one site, BCWP was greater than ACWP ensuring money was available to complete the project. On the other hand, the Model Budgeted Cost of Work Performed (MBCWP) had MCV values ranging from $3,000 to $385,000 over ACWP with one of the sites having a MBCWP of $8,100 under ACWP.

SITE	BCWP	MBCWP	ACWP	ACV	MCV
OE-21	26167	114102	26155	($12)	($87,947)
OE-13B	1637133	1878585	1493362	($143,771)	($385,223)
OE-23	60843	51733	59843	($1,000)	$8,110
OE-45	265761	409880	265795	$34	($144,085)
OE-32C	17144	20213	17130	($14)	($3,083)

BCWP= Budgeted Cost of Work Performed
MBCWP= Model Budgeted Cost of Work Performed
ACWP= Actual Cost of Work Performed
ACV= Actual Cost Variance (ACWP-BCWP)
MCV= Model Cost Variance (ACWP-MBCWP)

Table 6-6. Comparison of Model Estimate with Fort Ord Estimate

It is clear that the former Fort Ord cost estimates more closely approximated Actual Cost of Work Performed than those developed by the regression model. Thus the Fort Ord model is a better model. At first glance, it may appear that even though the MBCWP provided more money for the cleanup, having such large amounts of money being held rather than being used for other cleanup projects does not efficiently utilize taxpayers' money.

E. SUMMARY

The results of this research and the forecast model formulation provide an extensive and practical foundation from which to analyze UXO cleanup costs. By utilizing existing data and searching for parameters that can be used as independent variables, a regression equation can be achieved that will explain each variable's influence on the total costs of the cleanup project.

Even though the resulting Model Budgeted Costs ranged between $3,000-$385,000 above the actual costs, the model is a useful tool that DOD policy makers could utilize. This model could provide DOD with a quick cleanup cost estimation pocket tool that could be used when contemplating the closing of a military facility during future BRAC procedures. This model does not rely on expensive, time consuming and often complicated computer cost estimation programs, but is very straightforward and can be run on a laptop computer.

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VII. CONCLUSIONS AND RECOMMENDATION

This thesis demonstrates a model for predicting cost estimates of UXO cleanups. Utilizing existing data from the former Fort Ord, a three variable model was developed that could be used as a quick reference, pocket tool for Department of Defense policy makers when contemplating placing an installation on future Base Realignment and Closure lists.

Chapter I established the need for the research and outlined the questions to be answered. Chapter II provided an overview of major legislation affecting environmental cleanup of UXO. Additionally, Department of Defense Directives introduced the reader to an understanding of the importance of UXO cleanup. Chapter III addressed the phases associated with a non-time-critical removal action including Preliminary Assessment, Site Investigation, Engineering Evaluation/Cost Analysis, Removal Design and Action, and Post-Removal Action. Chapter IV listed the major players and their roles at the former Fort Ord Installation. Chapter V discussed methods of vegetation clearance and provided an overview of their pros and cons. Chapter VI covered the data, regression analysis, analysis outcomes, and a comparison of the mathematical model estimates versus the former Fort Ord estimates. This chapter provides conclusions, recommendations, and topics for further research.

A. CONCLUSIONS

The cost estimation program utilized at the former Fort Ord Installation proved to be a better estimator of actual cost required to successfully cleanup UXO than the developed regression model. This statement is supported by analysis discussed in Chapter VI of this thesis.

In light of the above statement, the developed cost estimating model using regression analysis could provide DOD officials with a quick, pocket tool for estimating the cost of UXO cleanup. Policy makers could save time and money, because the developed model uses only three variables to assess cost. Because there was a wide cost variance between the model costs and actual costs, additional variables could be added to enhance the results.

A major problem encountered during the writing of this thesis was the lack of complete and detailed information on all completed cleanup sites within DOD. The thesis analysis in Chapter VI focused on data from only one site because of the commonality found among the After Action Reports. DOD does not currently have a workable database that encompasses common data from all defense installations. Having a common database could enhance current processes and procedures associated with UXO cleanup.

Another problem encountered was that there was no standard cost estimation program currently in use throughout DOD. During research it was discovered that accurate cost estimation rested heavily upon the installation program offices and, because of this, they are allowed to use any cost estimation program they believe to be accurate and reliable. Because of this fact, cost estimation accuracy could vary greatly from one installation to the next.

A third problem encountered was the amount of environmental legislation affecting UXO cleanup. While researching vegetation clearance methods, it was discovered that many of the methods that were more economical to use, were eliminated from selection due to their conflict with one or more of the many governing regulations. Relaxing some of the regulations could provide for greater cost savings by freeing up alternative methods for selection.

B. RECOMMENDATIONS

Individuals who are tasked with providing DOD policy makers with cost estimate information for UXO cleanup should strongly consider utilizing this model as a basic tool. Because the model erred towards higher budgeted costs than actual costs in the majority of the estimates, this model would be fairly safe to use as a quick reference tool. Also, because there are many potential installations that could be assessed for a BRAC list, this model may prove to be a great cost and time saving tool during early selection.

DOD should seriously consider using this model and even providing research time into updating and enhancing the accuracy of the model.

It is highly recommended that DOD take steps toward standardizing the cost estimation process for UXO cleanup. One cost estimation program being used by some military components is the Remedial Action Cost Engineering and Requirements (RACER) system. The program was developed for the United States Air Force in 1991, but could prove to be useful throughout DOD following validity testing.

There are many other programs being used by civilian contractors that could prove to be better estimators of cost. The bottom line is that action needs to be taken to achieve a standardized program.

Another recommendation would be for DOD to provide decision makers at the component level with a basic laptop driven program. Such a program could be used to provide quick answers to UXO cleanup cost estimation questions within a tolerable range of accuracy. A more detailed cost estimate could be provided at a later time once authority to close an installation has been received.

C. FURTHER RESEARCH

The developed regression analysis cost estimation model is currently in the early developmental stages and could prove to be a valuable, cost saving tool if further refined. Expanding the scope of this research to include other installations would undoubtedly enhance this model.

A more detailed database of UXO cleanup costs is needed for this model and any existing model to better serve the Department of Defense. This thesis provides a basis for future thesis research and could easily be improved as more historical cost data become available.

Another area of further research that could be studied is combining many of the environmental legislations into a single legislation that encompasses the major benefits of each. The effects this would have on future cleanup projects and the potential cost savings could be analyzed.

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